Global Change in a Pacific Context

Atoll Adaptation Dialogue

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Outline

Background

Sea level rise

Waves

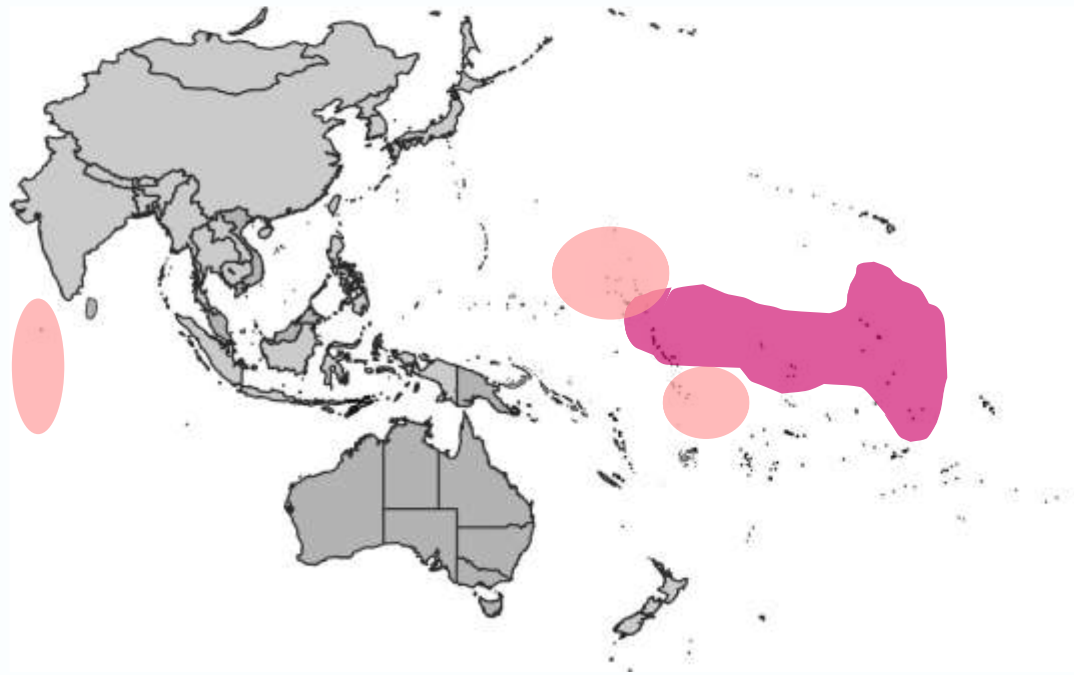
Tropical cyclones

Ocean acidification

SST and marine heat waves

Large scale drivers (ENSO)

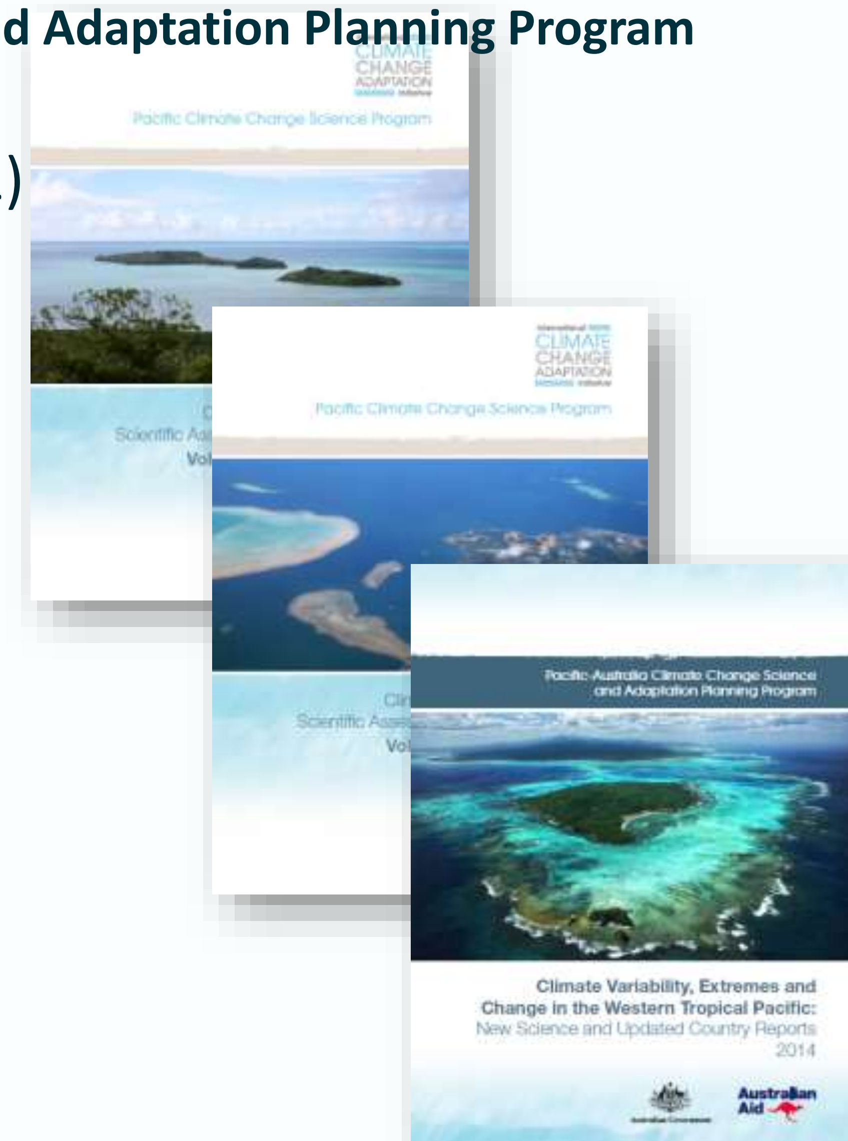
Rainfall & Drought



Climate Change Information for the Pacific

Pacific-Australia Climate Change Science and Adaptation Planning Program (PACCSAP)

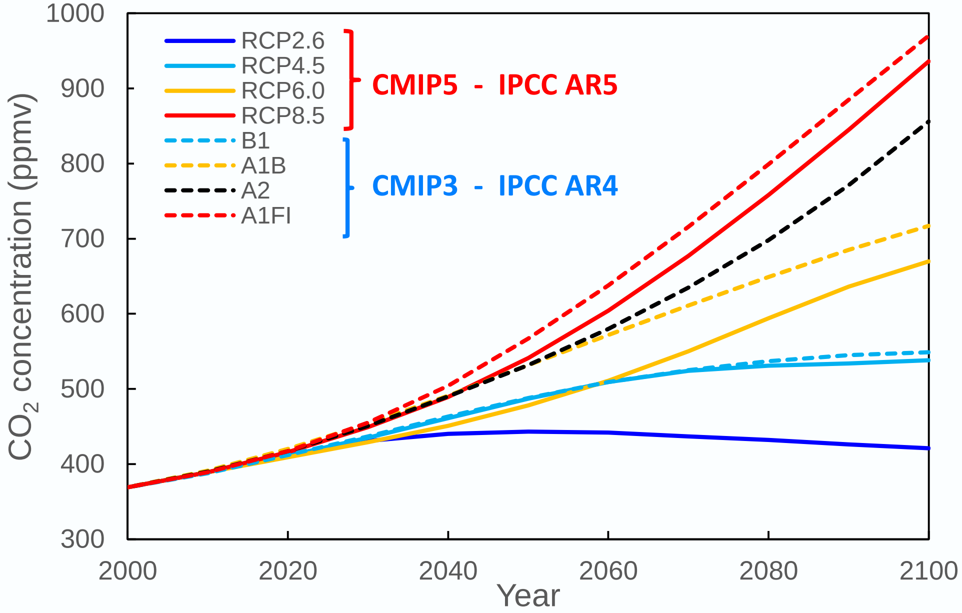
- PCCSP (2011) Region Overview (Vol 1) and Country Reports (Vol 2)
    - Based on CMIP3 climate models
- PACCAP (2014) Updated Science and Country Reports
    - Based on CMIP5 climate models, which included ocean biogeochemisty – projections of ocean acidification
    - Wave climate projections included in updated report



Emission Scenarios

- Temperature change predicted by climate models for scenarios used in the AR4 and AR5 assessment reports.
- The atmosphere has warmed approximately 1°C since pre-industrial times.

Scenario	Atmospheric CO_2 equivalent in 2100 (ppm)	Temperature Increase (°C by 2090-2099 relative to 1980-1999)	Scenario	Atmospheric CO_2 equivalent in 2100 (ppm)	Temperature Increase (°C by 2081-2100 relative to 1986-2005)
A1FI	1550	4.0 (2.4 – 6.4)	RCP 8.5	>1370	3.7 (2.6 – 4.8)
A2	1250	3.4 (2.0 – 5.4)	RCP 6.0	850	2.2 (1.4 – 3.1)
A1B	850	2.8 (1.7 – 4.4)	RCP 4.5	650	1.8 (1.1 – 2.6)
B1	600	1.8 (1.1 – 2.9)	RCP 2.6	490	1.0 (0.3 – 1.7)



IPCC AR6 cycle

- 3 special reports
  - **Special report on 1.5°C** – Released October 2018
  - **Special report on Oceans and Cryosphere** – due for release September 2019
  - **Special report on Climate Change and Land** – due for release 2019
- Sixth Assessment Report
  - Assessment reports from Working Groups 1, 2 and 3 due for release from 2020 onwards

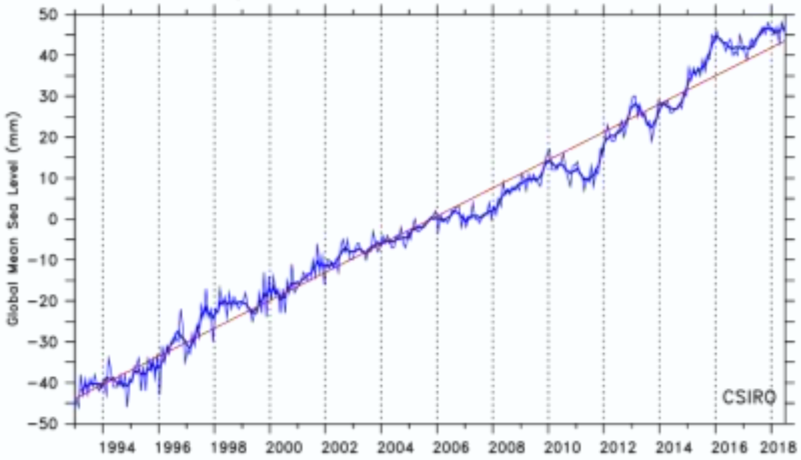
- **1°C has occurred and is likely caused by anthropogenic activities**
- **likely to reach 1.5°C between 2030 and 2052**
- **NDC's pledged under the Paris Agreement will result in global warming of more than 1.5°C**
- **By 2100, SLR would be ~ 0.1m lower with 1.5°C global warming compared to 2°C**
- **Limiting global warming to 1.5°C would require rapid and far-reaching systems transitions occurring during the coming one to two decades**

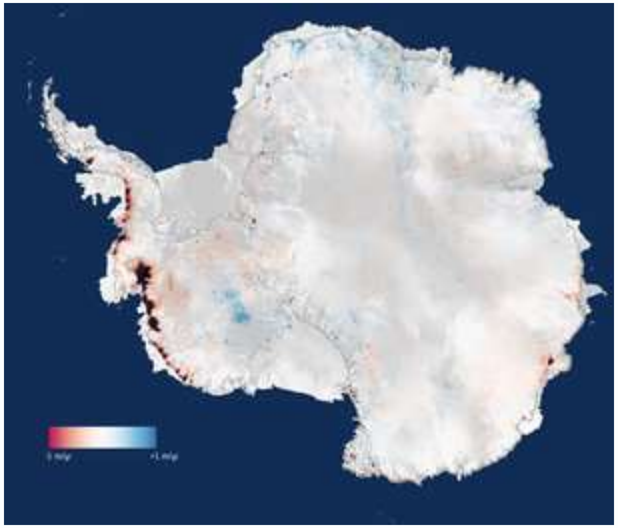
Sea level trends

Sea levels are rising at approximately 3 mm/y

Latest estimates for **the Antarctic ice sheet** show a **loss** of 2720 ± 1390 billion tonnes from 1992 to 2017, corresponding to an increase in global mean sea level of 7.6 ± 3.9 mm (approximately 10 per cent of the total).

(source: Australian State of the Climate, 2018)





Sea Level Rise

- Projections include:
  - Warming/cooling of the ocean (thermal expansion/contraction)
  - Ocean density, circulation

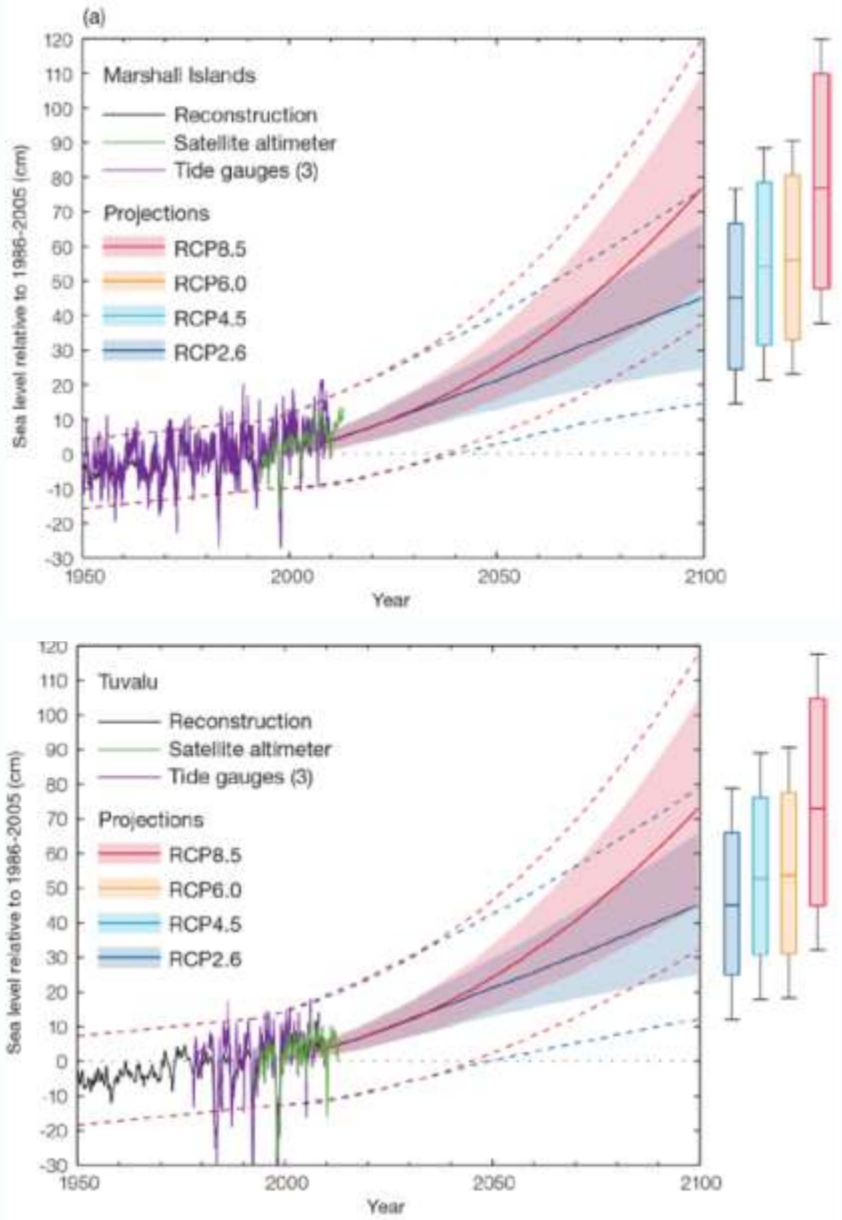
  CMIP5 Climate Models

  - Change in mass of glaciers and ice sheets (Antarctica, Greenland) and distribution of mass on the earth
  - Changes in terrestrial storage
  - Land movement (Glacial Isostatic Adjustment)

  Offline Models based on CMIP5 output and other information

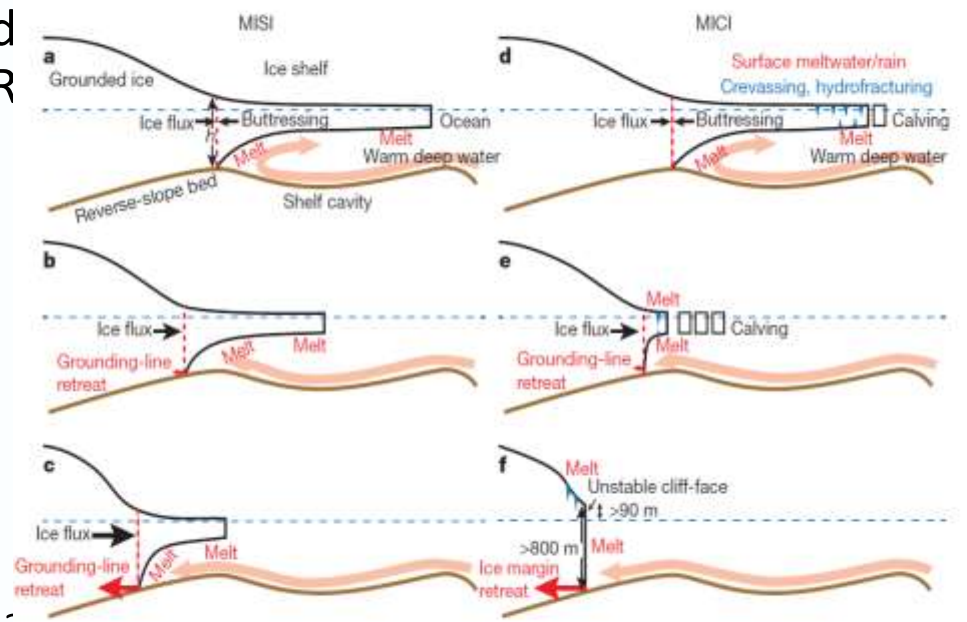
- Projections DON'T include:
  - Contributions from possible ice sheet instability from Antarctica

“Collapse of marine-based sectors of the Antarctic Ice Sheet, if initiated, would add no more than several tenths of a meter by 2100.” (Church et al, 2013)



Marine Ice Sheet Instability and Ice Cliff Instability

- DeConto and Pollard (2016) proposed that MISI and MICI could increase SLR projections by 2100 by a further 1 m
- Low confidence because the process has not been observed so far
- Significant ongoing research
- IPCC SROCC report will update SLR projections
- Several new recent studies (Edwards et al., 2019; Golledge et al, 2019; Bronselaer et al, (2018)) suggest that feedback processes that are missing in climate models would act to offset some of the SLR this century.

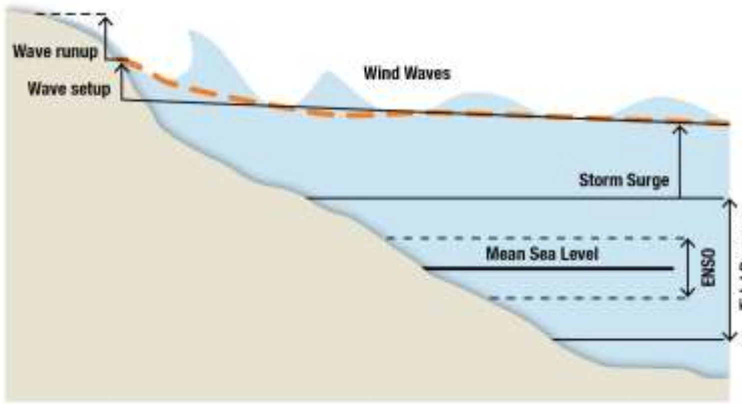


DeConto and Pollard, 2016

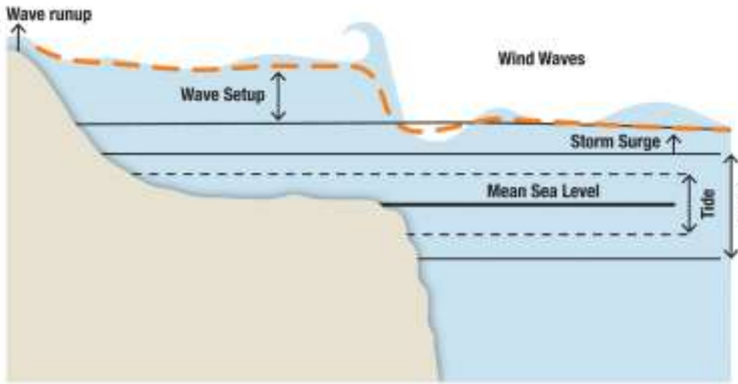
Understanding Extreme Sea Levels in the context of Atolls is important

1. Narrow and steep-shelved bathymetries are vulnerable to greater wave-induced extremes (wave setup and runup)
2. Modelling shows that as SLR increases, wind and wave setup decreases but wave energy reaching the shore increases

E.g. Hoeke et al, 2015 found a 10-20% in wind and wave setup but up to 200% increase in wave energy -> greater runup and overtopping



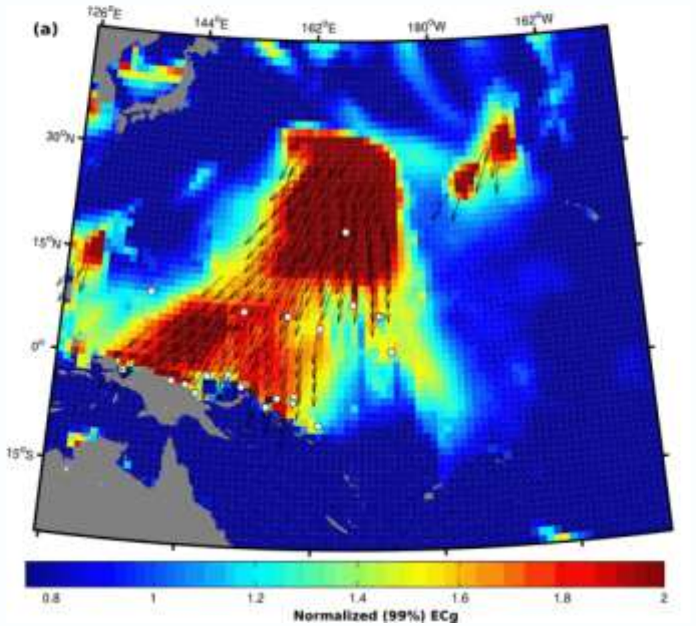
Typical continental shelf



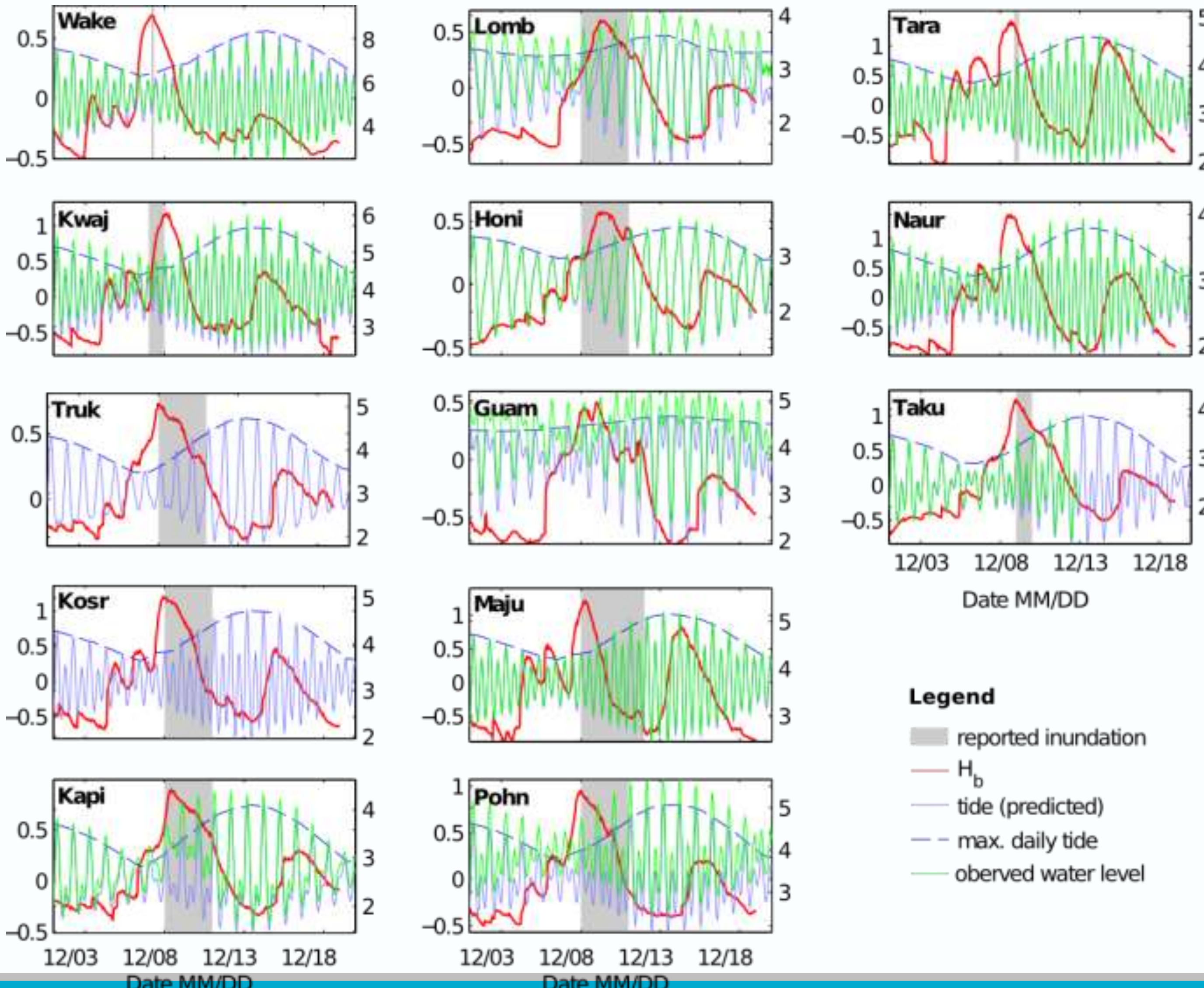
Typical atoll with fringing reefs

Waves

- Distant-source swell waves pose a major hazard for steep-shelved Atoll nations (Hoeke et al, 2013; Wadey et al, 2017)
- Source regions can be distant from the point of impact
- E.g. December 2008 event affected 6 Pacific nations including atolls of the Marshalls and Kiribati and originated in the far north Pacific



Waves and sea levels at time of inundation



Wave energy
Tide gauge observations
Predicted tides
Reported time of inundation

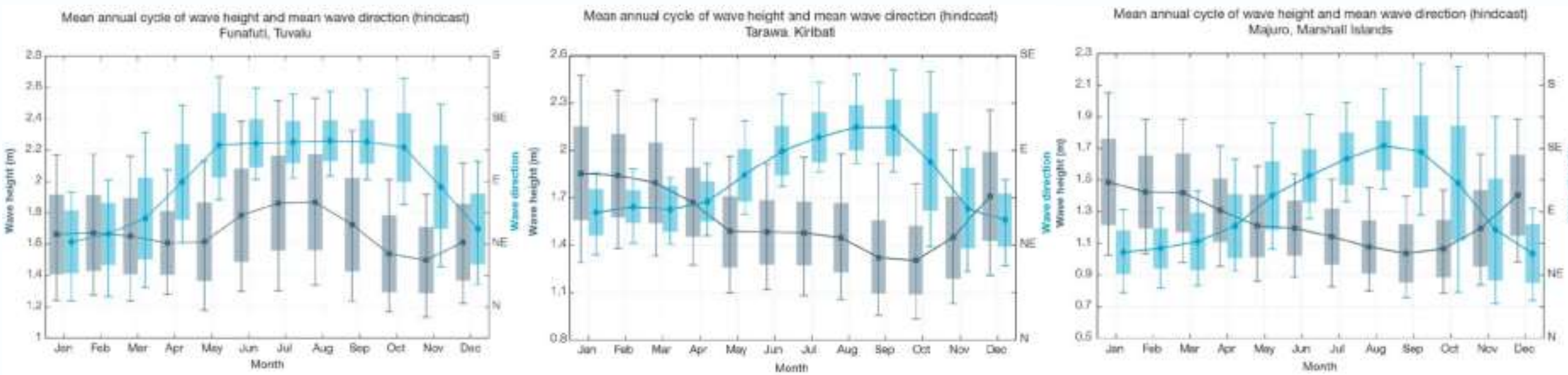
Tide gauges do not show elevated water levels at the time of wave impact

Source: Hoeke et al, 2013: Widespread inundation of Pacific islands triggered by distant-source wind-waves. Global Planetary Change 108: 128–138

Wave Climate

In situ wave data is scarce in the Pacific

PACCSAP (2014) country reports contain wave climate data (Hs, Tp and Dir) derived from model hindcasts



Boxes = 1 sd and bars =5 to 95% range

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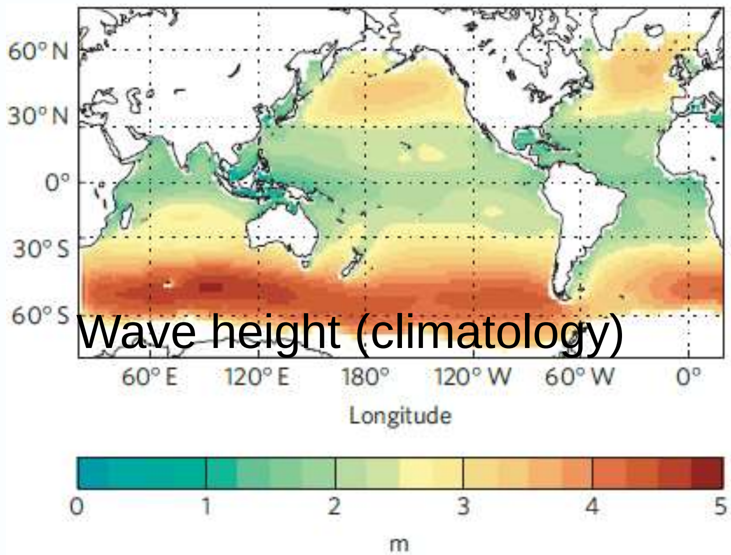
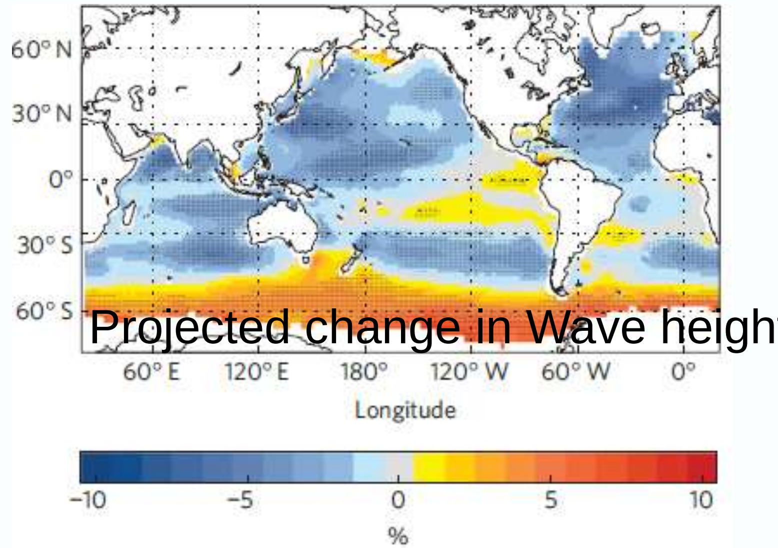
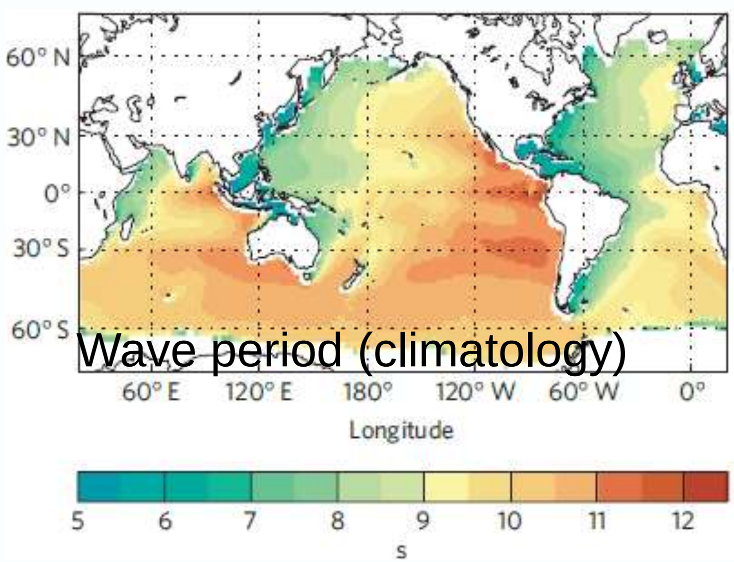
Future wave climate change



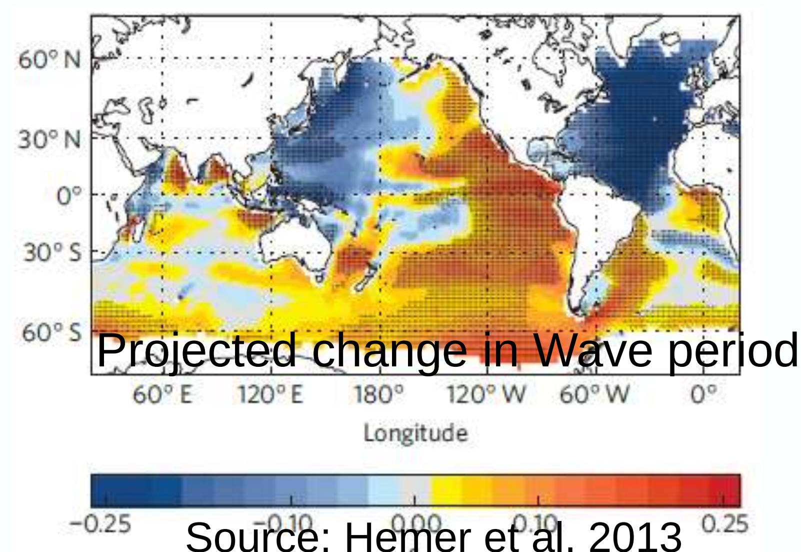
Wave height (climatology)



Projected change in Wave height



Wave period (climatology)



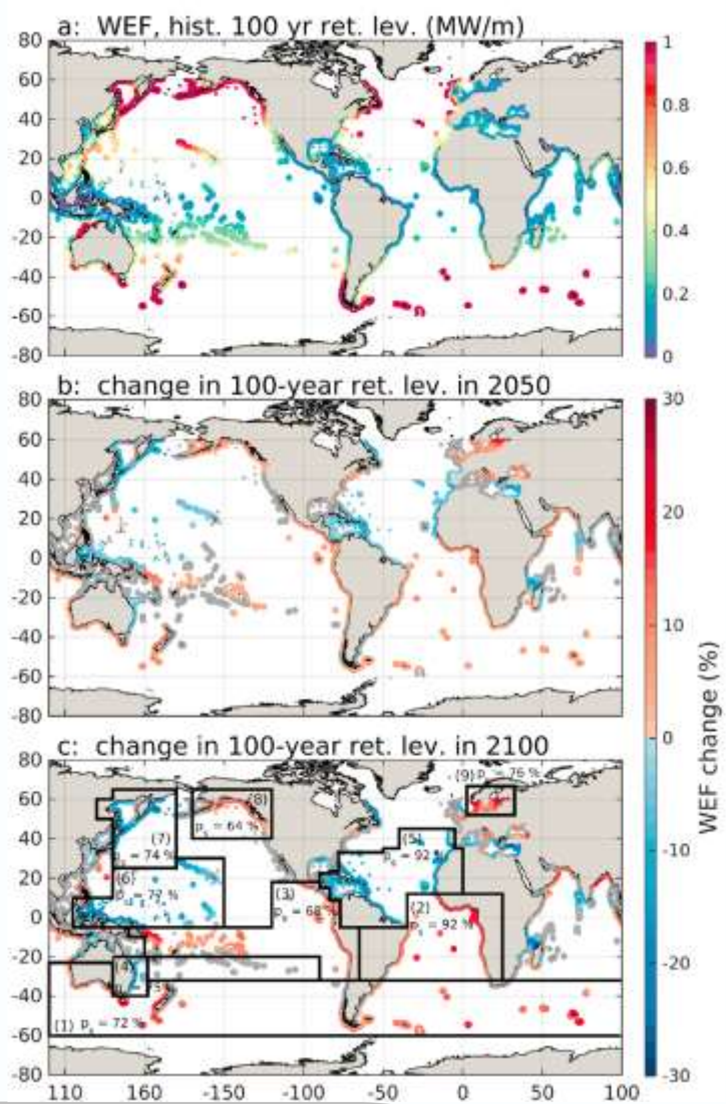
Projected change in Wave period

Source: Hemer et al, 2013

Future wave climate change

Future wave energy flux is calculated using future climate from 6 latest (CMIP5) climate models under RCP 8.5

30% increase in 100-year return level wave energy flux (the rate of transfer of wave energy) for the majority of coastal areas in the southern temperate zone



Source: Mentaschi et al, 2017

Tropical Cyclones

IPCC: *low confidence* in any long-term increases in tropical cyclone activity globally

TC frequency will either decrease or remain essentially unchanged,

TC intensity (maximum wind speed and precipitation rates) will *likely* increase

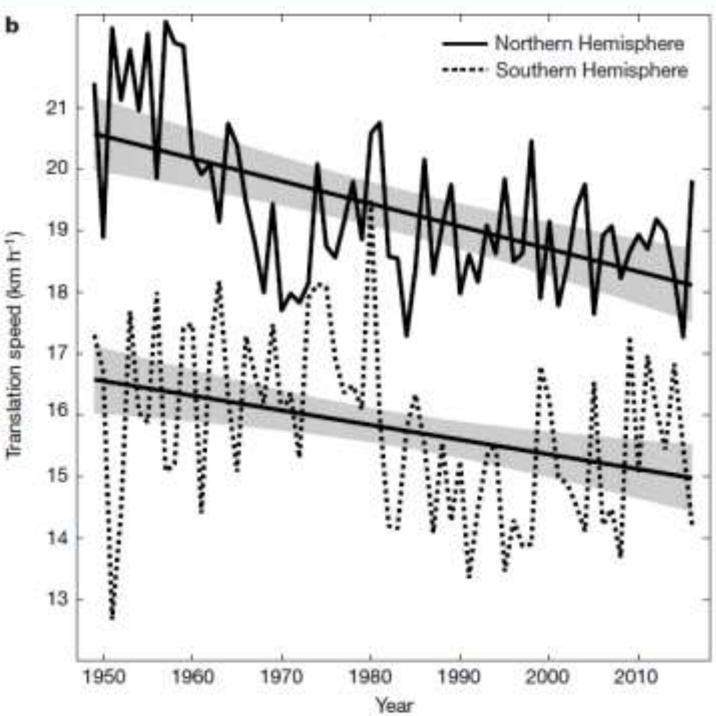
Rainfall intensity in TC’s is expected to increase ~ 7% per degree of global warming

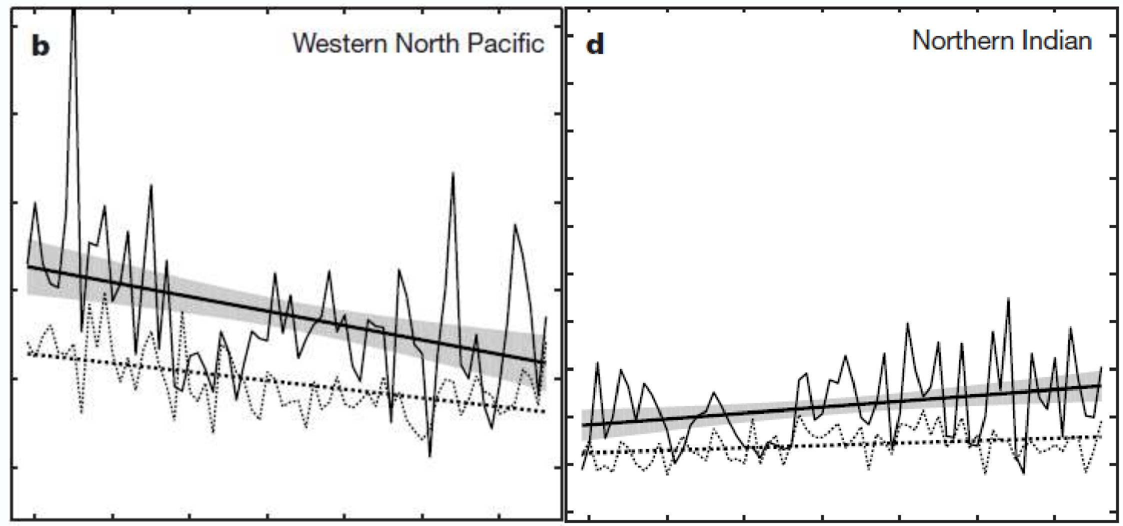
low confidence in region-specific projections of frequency and intensity

An increasing number of recent studies have employed “event attribution” to determine the role of anthropogenic climate change (usually in terms of rainfall intensity)

Tropical Cyclones

Projected expansion of the tropical zones -> TC steering winds become weaker and TC's slow down





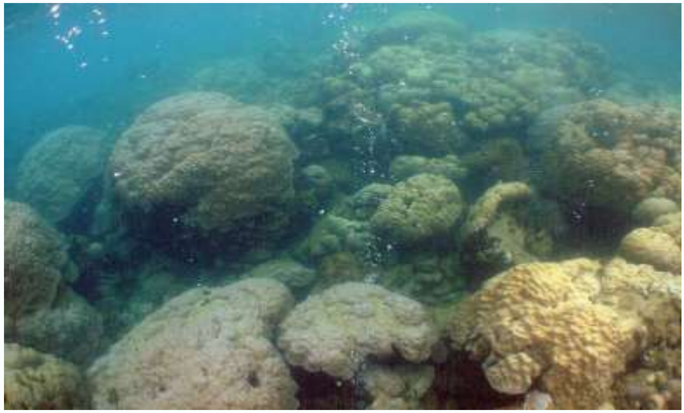
Source: Kossin, 2018

New studies find a poleward expansion of tropical cyclone tracks and eastward movement into the north central Pacific

Ocean Temperature and Marine Heat Waves

- ❑ 93% of excess heat in the climate system is absorbed by the oceans
- ❑ Extremes in ocean temperature (Marine Heat Waves) are becoming more frequent
- ❑ The interval between recurrent MHWs and associated coral bleaching events has decreased from about 30 years in 1980 to 6 years currently
- ❑ Marine heat wave days have doubled globally since 1982

(Sources: Hobday et al, 2016, Frölicher et al., 2018, Oliver et al., 2018a;b)



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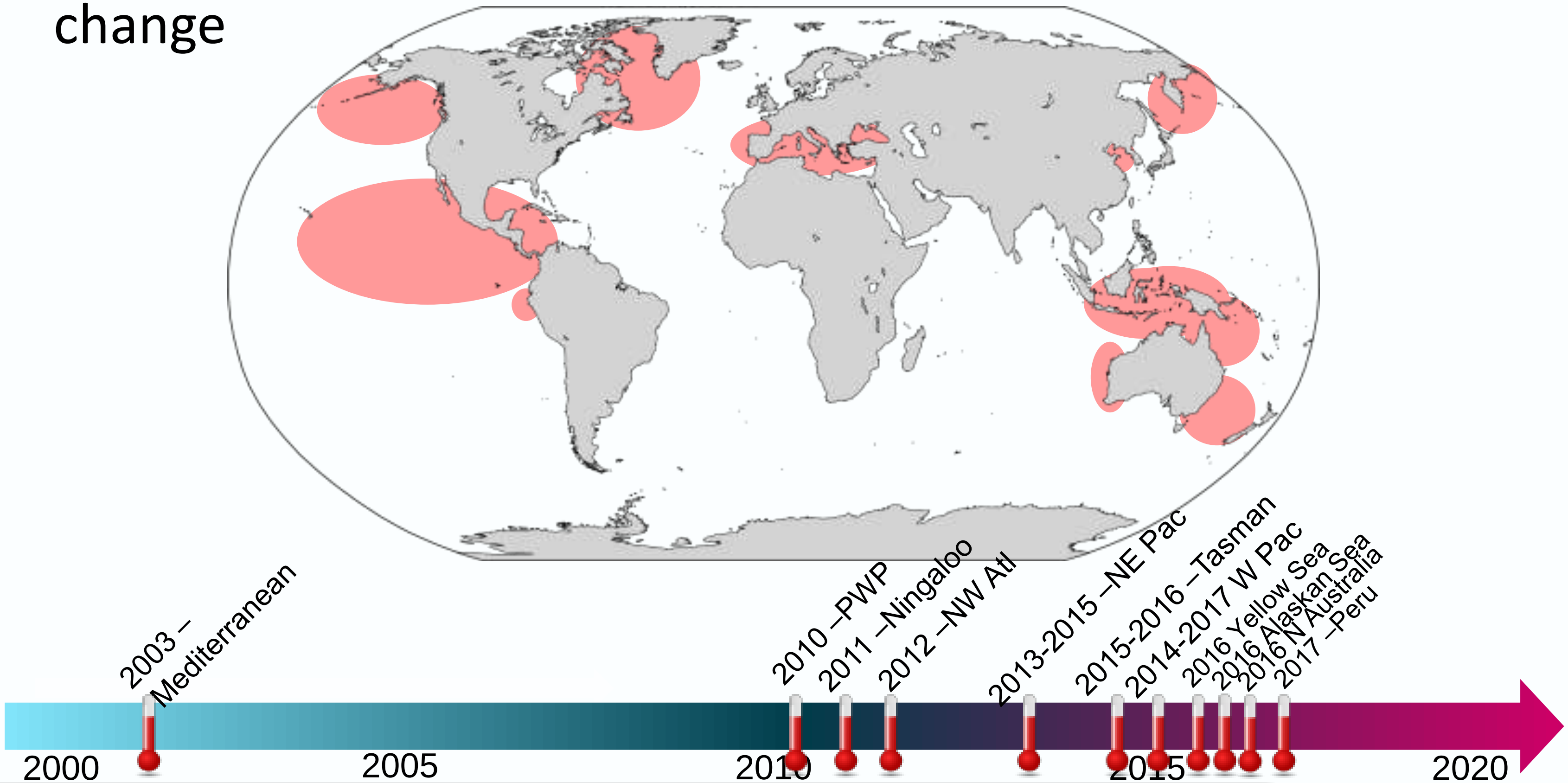
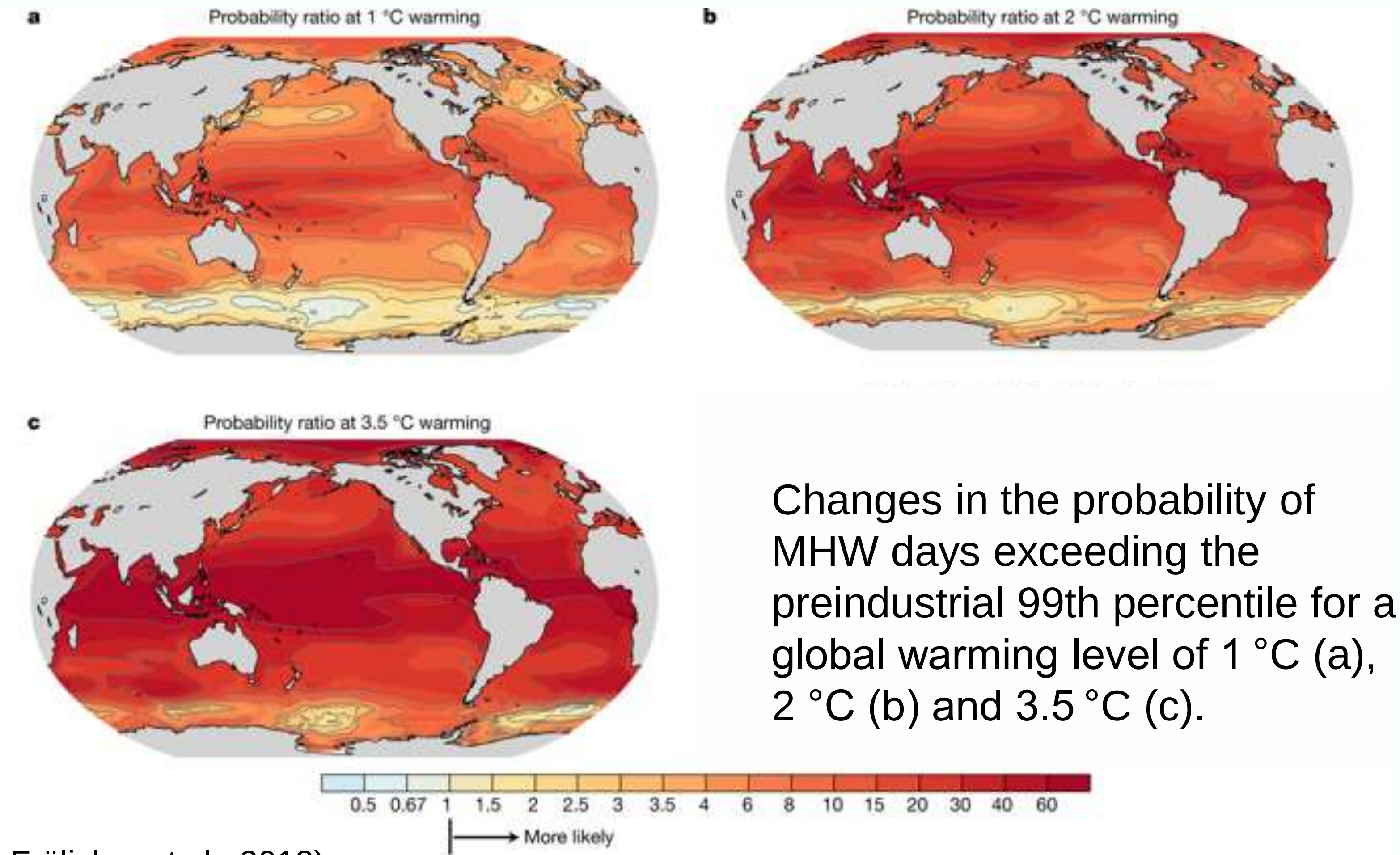
Ocean Temperature and Marine Heat Waves

- a quarter of the surface ocean experienced either the longest or most intense marine heatwave since 1982 in 2015/2016
- MHW since 2014 have mostly been fully attributed to climate change



Change in probability of MHW days

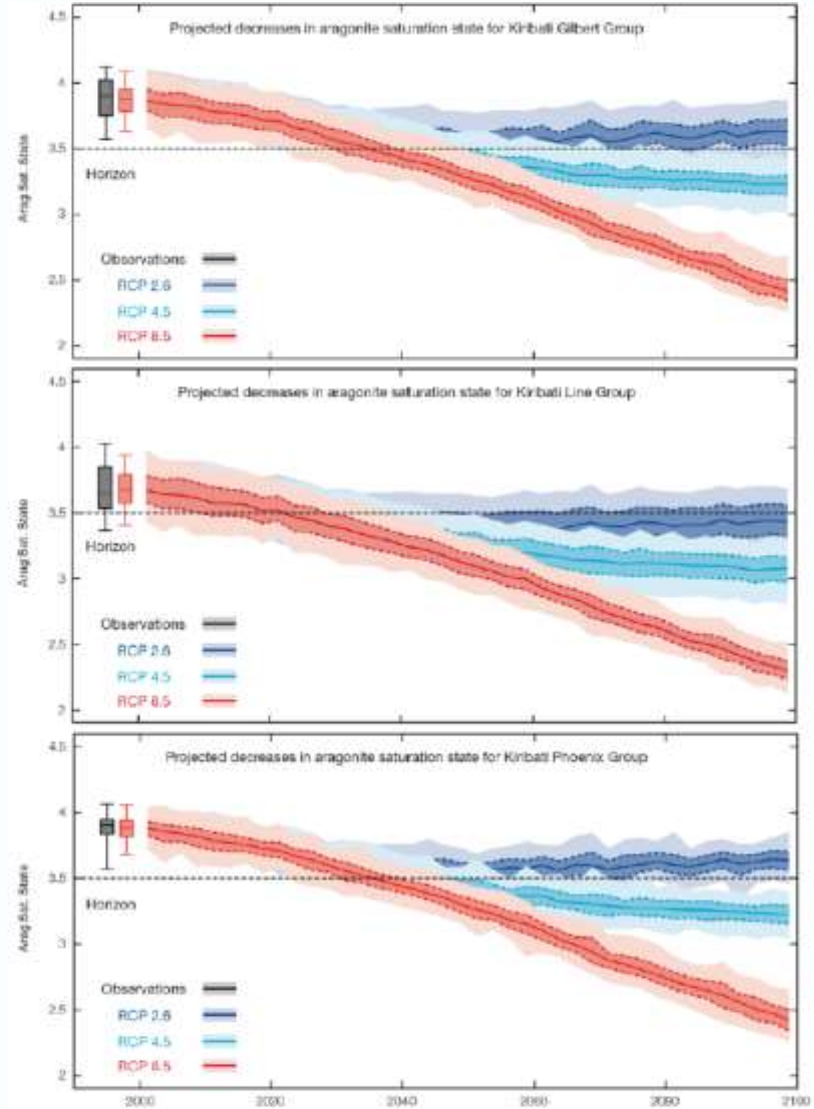


Changes in the probability of MHW days exceeding the preindustrial 99th percentile for a global warming level of 1 °C (a), 2 °C (b) and 3.5 °C (c).

(Source: Frölicher et al., 2018)

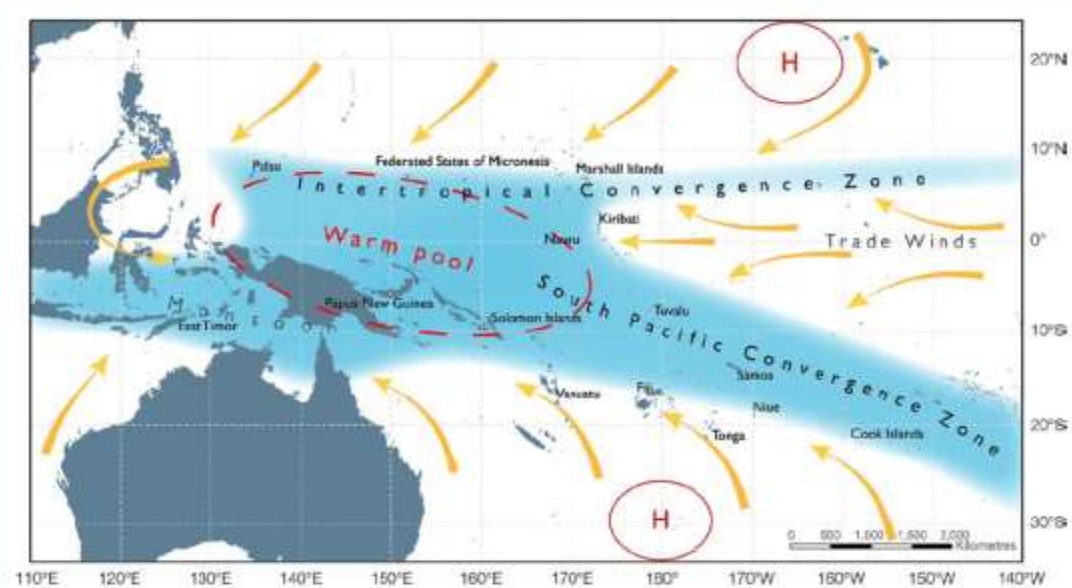
Ocean pH and aragonite saturation (Ω)

- Nearly half of the anthropogenic CO_2 emitted over the last 200 years has been absorbed by the oceans leading to ocean acidification
- Acidification impedes the ability of calcifying organisms to form their skeletons
- Ocean pH has fallen 0.1 units representing a 26% increase in the hydrogen ion concentration in seawater



Extreme rainfall and drought

- Rainfall expected to increase in the Marshalls, Kiribati and Tuvalu. The increase for a 1 in 20 year event is 1 to 7% RCP 2.6 or 8.5
- Drought is projected to decrease (source: PACCSAP report, 2014)
- Extreme El Niño frequency and La Niña frequency is projected to increase with the global mean temperatures with a doubling in the 21st century under RCP8.5 (Cai, 2014)



Challenges for Atoll Nations

- Atoll nations are very vulnerable to SRL and SL extremes including from distant-source wave events
- Limited ‘baseline’ data. i.e. What is our current likelihood of experiencing extreme sea levels? Limited in-situ observations (including bathymetry) on which to build and test models
- Range of factors contributing to extreme sea levels, e.g. Tides, Storm surge, Wind-waves and swell, Seasonal and interannual variability
- Sea level rise will reduce wave setup and wind setup but will increases wave energy reaching the shore
- Extreme rainfall is projected to increase and TCs translation speeds may decline
- Risks for coral ecosystems from SST increase and acidification
- Chance of multiple hazards coinciding is increasing


Thank you
For more information
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INTERGOVERNMENTAL PANEL ON climate change